was successful also so far as demonstrating the possibility of motion; but the apparatus was so imperfect that the balloon moved very slowly indeed, and another apparatus has to be made by the French experimentor. Instead of using common lighting gas, Prof. Ritchel resorted to pure hydrogen. His balloon had only 3,000 cubic feet measurement whilst Capt. Ardisson's wanted about 11,000. Capt. Ardisson's motor was composed of two very imperfect fans worked with the hand. Prof. Ritchel used a screw propeller moved with both feet, so that he had his hands free for working a horizontal fan, for ascending and descending at pleasure. Instead of constructing a spherical balloon, Prof. Ritchel had prepared a cylindrical one similar to the balloon *Delamare* tried fifteen years ago without success, in the open air. It is stated that Prof. Ritchel's success was very great, and the experiment will be tried again in Philadelphia, and probably soon in Paris. These experiments, M. de Fonvielle thinks, disprove the scheme advocated by the head of the French balloon service, Col. Laussedat, who, in a paper recently referred to in NATURE, suggested that the motive power should be applied to the balloon instead of being annexed to the car.

A VALUABLE sketch of the development of the natural sciences in Holland, has lately appeared in Leyden from the pen of Dr. B. van Haan.

THE late investigations of Count Wurnbrand, on the *loess* formations of the Danube in Moravia, lead him to the opinion that these deposits are entirely of an alluvial origin, and not due to diluvial disturbances. A large variety of fragments of charcoal, carved bits of bone and horn, flints, &c., accompanying the collections of animal remains found in these strata, point with great certainty to the existence of mankind at the time of their formation.

AN interesting archæological discovery is chronicled by the Berne papers. A forest in the neighbourhood is found to grow above a buried Roman town. Numerous edifices have been laid bare, and the various remains which have been unearthed show it to have been inhabited by the officers of the Roman forces, who occupied the strong defensive positions on the river Aar.

AMONG the more important scientific novelties in the German book trade during the past month, we notice the following works:—"Die Dolomit-Riffe von Südtirol und Venetien," 1ste Lief., Dr. E. von Mogsisovics (Vienna); "Die Reptilien und Fische der böhmischen Kreideformation," Prof. A. Frie (Prague); "Die Erdrinde und ihre Bildung," J. Lippert (Prague); "Vorträge über Geologie," F. Henrich (Wiesbaden); "Die Geologie und ihre Anwendung auf die Kenntniss der Bodenbeschaffenheit der oesterr.-ungar. Monarchie," F. von Hauer (Vienna); "Exkursionsflora für Mittel- und Norddeutschland," Exkursionsflora für Suddeutschland," Dr. M. Seubert (Stuttgart); "Taschenbuch der deutschen und schweizer Flora," E. Hallier (Leipzig); "Flora von Deutschland," Prof. A. Garcke (Berlin); "Die Schule der Physik," J. Müller (Brunswick); "Grundzüge der Elektricitätslehre," W. von Beetz (Stuttgart); "Lehrbuch der Physik," F. J. Pisko (Brünn); "Sonne und Monde als Bildner der Erdschale," J. H. Schmick (Leipzig); "Ueber Meerströmungen," E. Witte (Pless); "Anleitung zum Experimentiren bei Vorlesungen über anorganische Chemie," Prof. K. Heumann, III. (Brunswick); "Anleitung zur quantitativen chemischen Analyse," Prof. C. R. Fresenius, II. 2 (Brunswick).

WE have upon our table the following books:—"Outlines of Physiology," by Dr. McKendrick (Maclehose, Glasgow); "Choice and Chance," third edition, by W. A. Whitworth, M.A. (Deighton, Bell, and Co., Cambridge); "A Library Map of London and its Suburbs," by J. B. Jordan (Stanford); "A Geological Map of England," by Prof. Ramsay (Stanford); "A Geological Map of Ireland," by Prof. E. Hull (Stanford); "Grundzüge der Electricitatslehre," by Dr. W. von Bertz (Stuttgart); "A Candid Examination of Theism," by Physicus (Trübner and Co.); "A School Flora," by Dr. Marshall Watts (Warne and Co.).

THE additions to the Zoological Society's Gardens during the past week include a Black-faced Spider Monkey (*Ateles ater*) from East Peru, an Ocelot (*Felis pardalis*), a West Indian Rail (*Aremides cayennensis*), a Black Tortoise (*Testudo carbonaria*), a Common Boa (*Boa constrictor*) from South America, presented by Capt. J. Moir; a Himalayan Bear (*Ursus tibetanus*), an Indian Crow (*Corvus splendens*) from India, presented by Capt. J. S. Murray; a Rufous Rat Kangaroo (*Hypsiprymnus rufescens*) from New South Wales, presented by Mr. Thos. Wickenden; Six Herring Gulls (*Larus argentatus*) European, presented by Mr. Arthur Clarke; two Black-crested Cardinals (*Gubernatrix cristatella*) from South America, an American Thrush (*Turdus migratorius*) from North America, presented by Mrs. Arabin; a Black Saki (*Pithecia satanas*) from the Lower Amazons, a Spotted Cavy (*Cœlogenys paca*), a White Ibis (*Ibis alba*) from South America, purchased; a Chimpanzee (*Troglodytes niger*) from West Africa, deposited; a Reeves's Muntjac (*Cervulus reevesii*) born, six Upland Geese (*Bernicla magellanica*), a Brazilian Teal (*Querquedula brasiliensis*) bred in the Gardens.

THE MICROPHONE[1]

A LATE member of the present ministry, at a dinner given by the institution whose hospitality we experience in this hall, implied, on the authority of one of the leading members of the engineering profession, that invention, like cocktails and Colorado beetles, had taken root in America and had deserted old England. It is therefore to me, as I am sure it is to you, a great gratification to have brought before us an invention which is the offspring of British soil. During the last few months the science of acoustics has made marvellous and rapid strides. First of all we had the telephone, which enabled us to transmit human speech to distances far beyond the reach of the ear and the eye. Then we had the phonograph, which enabled us to reproduce sounds uttered at any place and at any time; and now we have that still more wonderful instrument, which not only enables us to hear sounds that would otherwise be inaudible, but also enables us to magnify sounds that are audible; in other words, the instrument which I shall have the pleasure of bringing before you to-night, is one that acts towards the ear in the same capacity as the microscope acts towards the eye.

I may point out, in the first instance, that the telephone and the phonograph depend essentially upon the fact—and a great fact it is—that the mere vibration of a diaphragm can reproduce all the tones of the human voice. In the telephone the voice is also made to vibrate a diaphragm, which, by completing an electric circuit, or by varying a magnetic field, or by altering the resistance or electromotive force of the circuit, produces effects at a distance which result in the reproduction of the motion of the diaphragm. But in this new instrument diaphragms are cast aside, and we have the direct conversion of sonorous vibrations, or sound waves, into forms of electrical action.

Now, if it had been the habit of the custom of this Society to give to the papers and discussions delivered here sensational titles, I should have been inclined to call the few remarks I am going to make to-night, "A Philosopher Unearthed." Prof. Hughes is well known to us all; he has been more or less associated with this Society since its first inception. Whenever he is in London he is amongst us. His instrument is well known to us as one of the most exquisite pieces of mechanism ever invented; and his works, though few, are known because they are sound. The chief characteristic of this philosopher whom I have succeeded in unearthing, is his extreme modesty. If he had been left to himself, I do not think we should ever have had the microphone here; but, by a lucky chance, he admitted me into his secret, and following, as I have done, all his steps, I am

[1] A lecture given before the Society of Telegraph Engineers, on May 23, by W. H. Preece, Vice-President Soc. T.E., Memb. Inst. C.E., &c., &c.

enabled to-night to bring before you the results of his labours, and they have been labours indeed. For months and months he has been working and straining at the ideas which at last he has elaborated into the microphone.

Now the chief characteristic of the apparatus I am going to introduce to you to-night is its great homeliness, its uncouth roughness, and its absurd simplicity. With common nails, with small pieces of wood, with halfpenny money-boxes, with plain sealing-wax, with the ordinary apparatus which every child has at its command, he has been able to attack nature in her stronghold—to ask her questions and receive back answers, and lay bare to us facts and thoughts which, though they have existed from time immemorial, are brought to light now for the first time.

Now, let us in the first place ask ourselves this question: What is sound? It is a very difficult question to answer in the short time at my disposal; but it is necessary that I should first say something to you about the nature of sound, and then say something about the nature of electricity, and show you how the one can be converted into the other.

Now, what is sound? While I am speaking to you I am setting the air in this room into vibration. The air of this room is composed of an infinite number of infinitely small molecules; every molecule is set in motion, and vibrates to and fro, backwards and forwards, like the bob of a pendulum, and between my mouth and every one of the ears in this hall there is a rapid but short excursion to and fro of every single molecule that comprises the atmosphere of this room; and it is the impinging of these molecules against the drum of the ear that produces that sensation called *sound*. But more than that, not only is the air of this room in this marvellous state of motion, but every piece of wood, every wall, every picture, everything in this hall at this moment, is almost, I may say, alive, trembling away, moving backwards and forwards, forming what are called sonorous vibrations. If the sound be loud enough, and the note deep enough, we can distinctly feel these vibrations. Sound is therefore the vibration in particular periods and particular phases of matter.

Now what is electricity? Faraday, the greatest electrician perhaps that ever lived, was asked that question, and he said the more he studied electricity, the more he unravelled its mysteries, the more mystified he became as to its cause and its origin; therefore it seems an act of impudence on my part or the part of any one else to attempt to answer the question, What is electricity? But great strides have been made since the days of Faraday; we know a great deal more now of the internal molecular action of bodies; we know that light, and heat, and sound are the mere action of those molecules of which matter is composed, and we feel sure, from the facts brought to our notice by the delicate apparatus of the present day, that electricity is simply a mode of motion, nothing more or less than the simple play of the molecules of matter. The truth of this will be made evident to-night by the wonderful connection which exists between sound—which we know to be a mere mode of vibration—and electricity, which will reproduce to us the effects of sound. To make this evident to us we must have a detector which will render apparent to us any electrical action that shall result in sound, and it fortunately happens that this marvellous telephone is an instrument of such extreme delicacy that it has made us acquainted with currents of electricity hitherto unknown, though their presence has been suspected. The telephone which Prof. Hughes has employed in his researches is as simple in its construction as all his other apparatus. It consists of two rough pieces of board clamped together. There is half the coil of an electro-magnet that probably has been in his possession since his early experiments to judge from its appearance. The magnet is a piece of steel rod that has been magnetized. The wire used, and which he has found extremely useful, is wire that was originally made for very different purposes, viz., for ladies' bonnets, and in front of this is placed a piece of ferrotype iron, well-known by those who have experimented with the telephone.

But what is the source of sound? It was necessary in making these experiments that he should have a source of sound. His source of sound was a small mantelpiece clock of French manufacture, which cost originally three or four francs. It has been in use many years, and has been in many parts of the world. It is repaired with great lumps of sealing-wax, but nevertheless it has, or ought to have, a pendulum, which gives a succession of beats, and those beats form a source of sound. Now, with this source of sound, and his beautiful scientific apparatus or detector, he started upon one of Sir Wm. Thomson's discoveries, viz., that wires alter their electrical condition when they are placed under strain. He took a piece of wire, applied weight to it, connected the clock with it, and heard nothing. He was not disconcerted, he applied weight after weight till he reached the breaking strain of the wire, and at the moment when the wire broke, he heard a rush or sound which he thought was an indication of what he was searching for, so he took the two ends of his wire and laid them together, placed his source of sound above them, and to his intense delight heard—what imagination perhaps assisted him in believing to be—a tick. He thought he was on the right track, and he then manufactured with a flat piece of brass for a lever, a pin for an axle, sealing wax for cement, and black wax for solder, and the uncovered bonnet wire for binding, a little apparatus which enabled him to apply constant pressure to the thing he was experimenting upon; in fact, by this means, he was enabled to produce what electricians call a "bad joint." To his intense delight he found that with this bad joint he was able to obtain sonorous effects. But this contrivance, simple as it appears, was a great deal too elaborate and complicated for his purpose, so he took two little nails—the little bright nails so much used in France—laid them side by side, not touching each other, and bringing the ends of the wire in contact with them, and laying between, or across them, a third and similar nail, he was able to reproduce, almost perfectly, the sound of the clock, and more than that he began to get indications of the sound or tone of the voice. He then used chains; he took my gold chain and put it beneath his little compressor, and with that we were able to speak with great ease. From that he tried filings, and found with matter in a finely divided state, that he was able to reproduce all effects of sound. At last he made little glass tubes about two inches long, filling them with white bronze powder which artists use, which is a mixture of zinc and tin, and he was able to exactly reproduce the tones of the voice. But in his experiments with carbon he was able to make what may be called quite an independent discovery. The carbon he experimented with was the common carbon used by artists in sketching their drawings, and this carbon he found to be a non-conductor of electricity. The idea struck him that this non-conductor of electricity might be made a conductor, and by various processes he at last arrived at a plan of boiling or heating this carbon in quicksilver. Carbon so heated in an atmosphere of quicksilver itself becomes permeated through and through with quicksilver, and by that means we get the mercury subdivided into an infinitely fine state. Probably mercury in this state as closely approaches the molecular as anything can do.

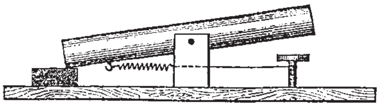

Fig. 1.

There is no apparent indication of mercury under the microscope, and yet we know that the carbon has been mercurised, because it is converted from a complete insulator into a conductor, and it has a metallic ring when it falls. Now then, having by these processes arrived at a substance which is remarkably sensitive to all the variations of the sound of the human voice, his next task was to construct these things into such a form as to make them telephonic transmitters. For that purpose he brought to his aid a very cheap kind of apparatus, a halfpenny money-box; inside this he placed his carbon transmitter, and as this discovery is not fenced in by fear of the patent or any other law, I am quite sure you will be glad to know how to make a Hughes transmitter. First he takes a piece of quarter-inch board about two inches long and one inch broad, and he raises upon that two thin brass bearings with a hole worked through by means of a pin for the support of the axis. He then takes a piece of carbon which has been mercurized about two inches long, which has a pin cemented to it near its centre, and which acts as an axis, and makes it into a lever. On the board he places a small piece of carbon, similarly treated, and upon this rests another similar sized piece of carbon, the two being connected by a piece of paper.

This is the end of one wire, and that the end of another wire; and on this diagram the arrangements of the circuit

are shown. S represents the source of sound, which I have shown on the black board. B represents the battery, and T the telephone. Now the battery is another remarkable speci-

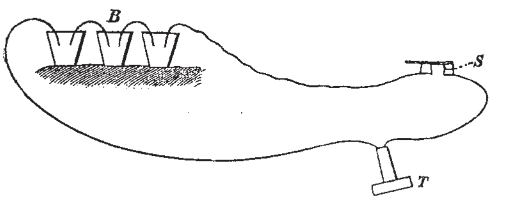

FIG. 2.

men of scientific manufacture. Three little glass tumblers are taken; at the bottom of each a coil of copper wire is coiled spirally. The copper wire is covered with a little sulphate of copper. The tumbler is then filled with moistened clay, and upon the top of the clay is placed a piece of scrap zinc. The three cells are placed in a cigar-box. S is what is called the box-transmitter. The tube-transmitter is shown on this diagram.

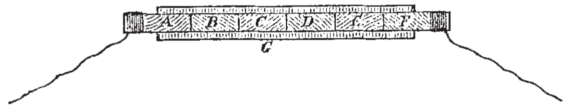

FIG. 3.

A is a glass tube about two inches long, and one quarter inch in diameter, inside which several pieces of mercurised carbon are inserted, touching each other with a pressure regulated by a screw fixed to each end. In that drawing there are six pieces of carbon, acting in this little transmitter; here (pointing) there are seven or eight, but that makes little difference, and the size of the carbon appears to be of little consequence. He has produced effects with carbon not larger than a pin's head. We shall show this by and by, but rather than disturb the order of these researches, I think it advisable in the next place to show you how this principle has been carried a little farther to produce what he calls the "microphone." This apparatus, drawn upon the board, is extremely sensitive. It will give evidence of nearly every sound; but in the microphone itself, which I have here, this extreme sensitiveness is carried to a still further extent. In point of fact, this is a microphone; but in this particular instance the pressure bearing between the two carbons is regulated by a spring fixed in this way, and it is so regulated that the transmitter is independent of any position in which it may be held. It is free to be moved in any direction in consequence of the pressure of the spring, but in one form of instrument this spring is dispensed with, and the pressure between the carbons is reduced to its greatest sensitiveness by making the two arms of this lever as short as possible. In the first machine he used, a piece of carbon was fixed on the top of an upright board, and a smaller piece was fixed down below. A cup-shaped hole was made in the upper piece of carbon, and a similar one in the bottom piece. Resting in these holes was a lozenge-shaped piece of carbon; and this lozenge-shaped piece of carbon rests with the greatest nicety upon its lower support, and is just in that position of equilibrium that the slightest atmospheric disturbance produces the effects which we are now about to show you. I think it desirable to tell you that you must not to-night expect distinct articulation. We have made a violent effort to make these experiments evident to you all. (Illustrations were given of speaking, singing, &c., &c.)

Now, the effects you have just heard have been produced by a transmitter similar to that drawn on the board. We will now repeat the effects with the machine on the table; and in order that you may judge of the effect—for Prof. Hughes desires that you should see there is no deception—we will connect this up, and use his old friend the clock to make its ticks, if it will, evident over the whole room. One of the greatest effects which this instrument produces is to render evident the tramp of a fly; and we have some nice little captives with which we will demonstrate that effect at the close of the meeting. (Illustration with clock.) To show that that is not due to the clock itself, Prof. Hughes will lift up the clock, when all traces of sound will have disappeared, and on putting it down again the sounds will be produced; so that the sound you hear is the sound of that clock which has been magnified. (This was so.)

Now, we have here a common quill pen, and Prof. Hughes will do as they do on the stage, pretend to write a letter; and I have no doubt if you listen attentively you will hear the scratching of his pen. (Illustrated.)

There are some peculiarities in this apparatus that are very striking. In the first place, though the sounds produced are very great, they do not interfere with each other. If you have a friend at the other end speaking to you, you can hear his voice distinctly working through your voice; and the result is you get a duplex action. Two or three persons can talk to each other without impediment or confusion.

Yet another point is, that the articulation is absolutely perfect. One of the great difficulties, both in the telephone and the phonograph, is getting the sibilant sounds reproduced—such as "s," and "c," and "sh," &c., which are produced by such extremely minute variations of the sonorous vibrations that they are lost in those instruments. Thus, if through the telephone you ask a person to "waltz," it will come out "walk," and names like my own, with the sound of "s" in it, would come out "Pree," not "Preece." In this transmitter one of its chief peculiarities is the fact that all sounds are faithfully reproduced; and it tends very much to upset the notion—Helmholtz's theory—that vowel sounds and other sounds are due to the superposition of waves upon waves of tones and over-tones. This apparatus shows almost unquestionably all these different properties; all these effects of intonation are due to differences in the form of the curve sent. Another peculiarity is this. I have told you that all in this room, every one's body while I am speaking, is alive with sound. If you take this transmitter and place it in front of your mouth, or put it on your forehead, or on the top of your head, or put it into your pocket, or upon your breast, it will still transmit sounds to distant places. Put it in a room, it does not matter where, it will reproduce the sounds. Put it anywhere in a drawing-room where there is a piano, you will hear the sounds of the piano faithfully reproduced. It is as you see a marvellously rough affair. You may throw it up, kick it about, or do what you like with it, it will always act. Here is the identical box that Prof. Hughes made two or three months ago. It has never been touched, it has been always at work, and never needs repair.

These are some of the peculiarities of his instrument, and I daresay some of you would like to know a little about its theory. We have here two points in contact, and those two points in contact complete an electrical circuit. The electric current that flows through that circuit depends for its strength entirely upon the obstacles or resistance in that circuit to the flow of the current; an alteration in any shape or form in the resistance of that circuit will result in the increase or decrease of the strength of the current flowing, and upon this diagram I have made a rough attempt to give you an idea of what occurs.

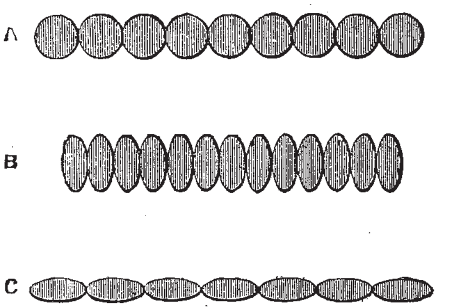

FIG. 4.

You must not conceive these round balls are molecules themselves, they are merely meant to represent the sphere of action of each molecule. In a normal state the molecules rest against each other, as shown by the upper line. When from any cause pressure is increased, they are contracted, as shown in the second line; when from any cause the pressure is decreased they expand, in the form shown on the other line. While I speak to you, the air of this room is thrown into vibration, the mass of air being subdivided into molecules in compression and molecules in extension. In a long wire these successions of compressions and extensions compensate each other; but when we break up a body into infinitely small parts, when we make less contact between two bodies, as shown there, and isolate the

portion of the sonorous wave in compression from that in extension, the result is that we have a variation in the resistance of the line. Now this variation in resistance depends upon the compression and dilatation of the molecules. They depend upon the tone of the voice, and the result is the resistance of the current varies with its variation of pressure, and at the distant end we have currents varying exactly as the voice varies, and reproducing on the telephone all the effects which we have seen. Hence follows the action of the microphone, and the action of the transmitter is one which depends upon the variation produced in bodies by the sonorous vibrations of the voice. As I am now speaking at that telephone, all the molecules of that transmitter are thrown into this elaborate series of compressions and dilatations. The current is varied; it goes to the room below, and is reproduced upon the telephone, as we have heard. Hence the effect is due to the difference of pressure, as is proved by using atmospheric pressure, and applying heat; and any large increase of pressure results in sound being reproduced.

No one has ever been nearer a great discovery than Mr. Edison. His telephone is based on the variation of resistance due to pressure. He used carbon and finely divided matter, but he worked on the idea that the difference in pressure was produced by the vibrations of a diaphragm. Had he thrown away his diaphragm he would have forestal'ed Prof. Hughes in this respect, and found that the sonorous vibrations themselves produced this difference of pressure. The great secret of Prof. Hughes's discovery is that sonorous vibrations and electrical waves are to a certain extent synonymous.

Now as to the uses to which this instrument is capable of being applied. It has been applied to surgical purposes in the form of the stethoscope. Though it does not show very markedly the beats of the heart, because they are more mechanical thumps than sonorous vibrations, yet it will show the injection and ejection of air in the lungs, and for many other surgical purposes it must become a valuable instrument. It admits us to some of the mysteries of insect life, and by its means we can hear sounds emitted by insects which have never been heard before. Going further it has enabled the deaf to hear; deaf persons who never heard a telephone before have been able to hear distinctly. It has enabled us to hear the physical operation which goes on in the process of crystallization of bodies and other things which before were wholly inaudible; and in fact it is impossible to say to what uses it may not be put.

It is rather remarkable that in an excellent paper read before the American Electrical Society, the author, Mr. Pope, makes these curious remarks:—

"The most striking results are to be looked for in the direction first pointed out by Mr. Gray, for the reason that if an effectual method of controlling the resistance of the circuit by means of atmospheric vibrations can be discovered, the source of power, which in this case is the battery, may be augmented to any required extent. It is not to be denied that the problem thus presented is one of exceeding mechanical difficulty, but there is no reason to suppose that it may not be successfully solved. It is to the development of this variety of the speaking telephone rather than to that of the magneto instrument that inventors will find it most advantageous to turn their attention, for I hazard little in saying that the latter has already reached such a surprising degree of efficiency, as to leave comparatively little more to be done within the necessary limitations which have been pointed out."

Mr. Pope throws out what has been done with the exception of the supposed mechanical difficulty, and that has been got over by a halfpenny money-box.

Now one very pleasing and gratifying circumstance attaches to this discovery of Prof. Hughes: he has thrown it open to the world, and by that means he has no doubt checked that species of immorality—I don't know what else to call it—connected with the infringement of the patent law, as regards the telephone. He allows us all to manufacture microphones for ourselves, but even he has been subjected to rather a peculiar incident. One impulsive and active gentleman who was present at the Royal Society the other night when Prof. Hughes first described his invention, went home and made himself a microphone, wrote a description of it and sent it off post haste to Paris. A short time afterwards Prof. Hughes himself with great care prepared a paper to be read before the French Academy, but to his great surprise he found that he had been forestalled, a description of his instrument had already appeared in the Paris prints from the gentleman in question.

There are lessons to be learnt from this discovery, and the principal lesson is—we can all of us with the means at our disposal cross-question nature and find out her secrets, and there are many secrets which yet remain to be divulged. We learn the wonderful connection which exists between all the physical forces: heat, and light, and electricity, and magnetism, are all co-related, and it has come to this, that what boys have said in joke has come to pass in earnest. We have been able to convert electricity into light, and light into electricity. We are now able to convert electricity into sound, and sound into electricity, and thus we are enabled to see the thunder and to hear the lightning.

THE SCIENTIFIC AIMS AND ACHIEVEMENTS OF CHEMISTRY[1]

MORE than a generation has passed away since my predecessor in the chair of Chemistry, Prof. Bischof, who was so full of merit in the domain of chemical geology, held the high office which the friendly confidence of my colleagues has entrusted to me for the ensuing university year. Since that time chemistry has undergone important changes, and its position upon the German high schools has also become an essentially different one.

At that time a general discouragement had taken root amongst the most eminent chemists. It was believed that all speculation had to be dismissed from the field of chemistry, and particularly that all atomistic considerations had to be discontinued, because whole categories of facts could not be made to agree either amongst each other, nor with the general theoretical views of that time.

At our high schools at that time chemistry was only taught from the chair; very often by teachers who were essentially appointed for other subjects. At most of the universities the students could be admitted to practical work only by favour of the teachers, and even Liebig's laboratory at Giessen, the first of all educational laboratories, only just then received its interior arrangement.

How different now! Well aware of its task and its aims, scientific chemistry, in close connection with physics, advances slowly, it is true, but with self-reliance and a certain confidence. Each university has its special chair of chemistry, many indeed have several. Richly furnished laboratories, and very often luxurious edifices, are at the disposal of chemical students in nearly all German universities, and the chemical lectures are the best frequented ones almost everywhere.

All this and also the circumstance that it is just a chemist who is able to day, as a representative of the entire university, to speak to the entire university from this place, proves, doubtless, that our science is now generally recognised to the extent it merits. But as on many sides it is over-estimated, it is yet more frequent, on the other hand, that its scientific right of existence is doubted. While outsiders who may occasionally have seen a chemical experiment, or may have heard of the grand applications of chemistry to practice, declare chemistry to be the finest science of all, although they may not be able to form an idea concerning its scientific aims, other one-sided representatives of so-called humanistic studies, who also mix up the applications of chemistry with its scientific task, tend towards the unjustifiable view that chemistry ought really to be taught only at polytechnic schools, but not at the "universitas litterarum."

The propagation of such erroneous conceptions renders it the duty of the chemist to appear as the defender of the science he represents, and it will doubtless be considered fully justified if to-day I try to explain to you the scientific position of chemistry and its participation in the great progress of universal science.

Chemistry has often been designated as the sister of physics, and both subjects are in reality so nearly related, their domains are so contiguous, that the layman cannot understand the difference, and that even the scientific man can hardly fix the limits.

Chemistry and physics together form that group which may be designated as *general natural science*, inasmuch as the occurrence of their materials of study is unessential, and the laws recognised by them are valid everywhere. Astronomy, geography, geology, botany, and zoology (the latter including those more special subjects treating of man, and which form the scientific part of medicine), all these, which ought to be comprised under the

[1] Address delivered on assuming the Rectorate of the Rhenish Friedrich-Wilhelms-University of Bonn, October 18, 1877, by Prof. Aug. Kekulé.